PD-200323

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04B 7/208, 1/713

A1

(11) International Publication Number: WO 99/49591

(43) International Publication Date: 30 September 1999 (30.09.99)

(21) International Application Number: PCT/IE99/00015

(22) International Filing Date: 23 March 1999 (23.03.99)

(30) Priority Data:

S980213	23 March 1998 (23.03.98)	IE
980749	8 September 1998 (08.09.98)	IE

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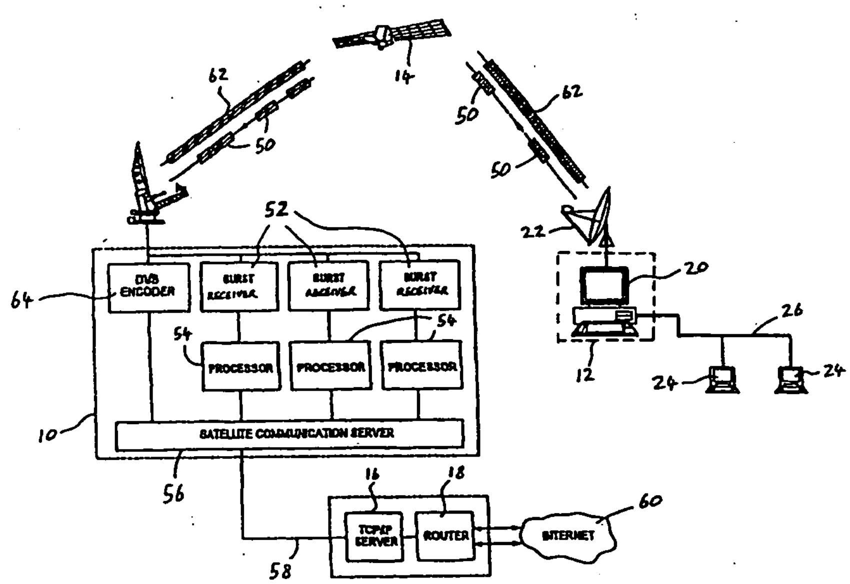
(81) Designated States: AU, BR, CA, CZ, HU, IL, IN, JP, KR, MX, NZ, PL, SK, US, ZA, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: DATA PACKET SATELLITE COMMUNICATION SYSTEM



(57) Abstract

A satellite communication system comprises a central broadcast station (10) in satellite communication with a plurality of user terminals (12) each of which can make requests for broadcast data from the central broadcast station. Each user terminal includes means (Fig. 2) for sending each user request as one or more data packets (50) each of which is transmitted as a modulated carrier whose frequency is randomly selected from a set of N predetermined frequencies common to all the user terminals. Each data packet includes data identifying the particular user terminal from which it originates, and the central broadcast station includes N channels (52/54) each arranged to receive and demodulate data packets transmitted at a respective one of the N carrier frequencies.

DATA PACKET SATELLITE COMMUNICATION SYSTEM

Technical Field

This invention relates to a satellite communication system comprising a central broadcast station in satellite communication with a plurality of user terminals each of which can make requests for broadcast data from the central broadcast station.

Background Art

There is at present a need to provide high speed data communication links in order to carry TCP/IP internet traffic between small user satellite terminals of around 90 cm diameter and a central broadcast station, herein referred to as a hub station. Such systems have been proposed in the past but suffer from network congestion and failure due to high peak traffic loading. In such systems the user requests are generally transmitted as data packets from the user terminal via satellite to the hub station. If many users transmit requests simultaneously, so-called packet collisions occur as a large number of data packets arrive at the hub station at the same time.

It is an object of the present invention to provide an improved satellite communication system, in particular for, but not limited to, internet traffic, in which the incidence of packet collisions is reduced.

Disclosure of Invention

Accordingly, the invention provides a satellite communication system comprising a central broadcast station in satellite communication with a plurality of user terminals each of which can make requests for

broadcast data from the central broadcast station, wherein each user terminal includes means for sending each user request as one or more data packets each of which is transmitted as a modulated carrier whose frequency is randomly selected from a set of N predetermined frequencies common to all the user terminals, each data packet including data identifying the particular user terminal from which it originates, and wherein the central broadcast station includes N channels each arranged to receive and demodulate data packets transmitted at a respective one of the N carrier frequencies.

Thus, in operation of the system, each user terminal transmits requests to the hub station as a series of data packets distributed in time, with successive data packets being sent at respective frequencies randomly selected from the given set of N frequencies. In other words, the user terminal "hops" between frequencies, and consequently this process is known as frequency hopping.

The probability of two packets arriving on one of the N frequencies at the hub station at the same time is significantly reduced compared to the case of all packets being transmitted and received on a single frequency, and the origin of each data packet is determined from the identifying data included within the data packet rather than the frequency on which it is transmitted.

Frequency hopping systems are known in the art. However, in conventional frequency hopping systems the changing between frequencies is performed according to a predetermined sequence which is known by the transmitter and receiver. A single receiver is normally used, which

changes the frequency on which it receives according to the predetermined sequence in step with the transmitter.

Using the present invention, there is no need for the hub station to know the sequence in which the user terminal transmitters hop between frequencies and thus truly random frequency hopping can be achieved.

Preferably each data packet includes a preamble containing, in addition to the user terminal identifying data, a plurality of bits which alternate in value, i.e 101010101...etc. As is described below, these allow the correct frequency of the received data packets to be accurately evaluated despite frequency drift due to component tolerances and propagation over the satellite link.

Brief Description of Drawings

An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Fig. 1 is a block diagram of a two-way satellite communication system according to the embodiment of the invention,

Fig. 2 is a block diagram of the frequency hopping transmission circuit in the user terminal of Fig. 1, and

Fig. 3 is a block diagram of the data packet clock recovery scheme.

Description of Preferred Embodiments

Fig. 1 illustrates the overall two-way satellite communication system, which comprises a hub station 10 in satellite communication with a PC-based user satellite terminal 12. Although only one user terminal 12 is shown, it will be understood that the system includes many such terminals and the description of the terminal 12 herein will apply to all such terminals.

In operation a user can make a request for information from the internet, and this request is sent as one or more data packets 50 from the user terminal 12 via a satellite 14 to the hub station 10. The hub station 10 is connected to a TCP/IP server 16 and router 18 allowing the request to be passed onto the internet 60. When the requested information is retrieved from the internet it is transmitted back from the hub station 10 via the satellite 14 to the user terminal 12.

The first stage in this general procedure is the transmission of the user internet request, or IP request, as a data packet, or number of data packets, from the user terminal 12. To this end the user terminal 12 comprises a personal computer (PC) 20 which contains a transmit interface card (Fig. 2), and which is connected via such card to the integrated feed (not shown) of a small satellite dish 22. The transmit interface card allows the computer 10 to interface with the dish 22. The PC 20 may be connected to a network of computers 24 via a LAN 26 and can receive IP requests from one or more of the computers in this network.

The interface between the PC 20 and the dish 22, as provided by the transmit interface card, is schematically shown in Fig. 2. In the transmit interface card digital

IP request data from the PC 20 is first passed to a first in, first out (FIFO) buffer 28, which is essentially a variable length shift register. The buffer collects all the data corresponding to a given request (or, where the IP request is to be transmitted in more than one data packet, for the portion of the IP request data next to be transmitted) and then passes this on to be encrypted at 30. The length of the request or portion thereof, and hence the activation of output from the buffer, is determined by control logic 32.

At 34 a preamble is generated for the IP request data or portion thereof. The preamble is, in this embodiment, 100 bits long, where the first 56 are bits which alternate in value, i.e. 101010101...etc., and are used to correct for frequency drift as will be described, the next 24 bits define a word unique to that request data or portion thereof, and the final 20 bits contain header data. The unique word acts as a tag for each data packet and is also used for synchronisation purposes. The 20 bit header contains the length of the data packet. The IP address of the user terminal which originated the IP request is contained within the body of the data packet. This preamble is attached to the encrypted request data in a multiplexer 36.

The transmit interface card also contains a local oscillator 38 which is enabled to generate IF carrier signals on any one of N different frequencies (in the present embodiment N=8). According to the frequency hopping scheme, each successive data packet is transmitted at a carrier frequency which is chosen at random from the set of N possible frequencies. The control logic 32 determines when a new data packet is

ready for transmission and thus instructs the local oscillator 38 to choose a new frequency, which may be randomly the same as the previous frequency but will in general be different. The random choice of a new frequency is effected by using a standard random number generator 40.

The data packet including preamble is passed from the multiplexer 24 to a differential and convolutional encoder 42, and then passed to a mixer 44. At the mixer 44 the random frequency carrier signal generated by the local oscillator 38 is phase modulated by the data packet using binary phase shift keying, as is well known in the art. The modulated signal is then passed via a band pass filter 46 and transmission enable gate 48 to the integrated feed (not shown) of the satellite dish 22. In the interface circuit, timing, synchronisation and transmission enable are all determined by the control logic 32.

The satellite dish 22 is preferably a standard 90cm diameter earth station. The integrated feed carries out the functions of frequency up-conversion to microwave carrier frequencies and provides transmission at relatively low powers, typically of about 250 mW. The data packets 50 from the user terminal 12, thus encoded, frequency hopped, and frequency up-converted, are transmitted, typically at 16 kBits per second, to the hub station 10 via the satellite 14. It will be understood that each of the N IF carrier frequencies generated by the local oscillator 38 will be up-converted to a different microwave carrier frequency by the integrated feed, so the principle of transmitting each packet at a random one of N different carrier frequencies is

preserved during the microwave transmission to the hub station 10 via the satellite 14.

Referring again to Fig. 1, the hub station 10 contains N channels each containing a burst receiver 52 and a processing unit 54 (for simplicity only three such channels are shown in Fig. 1). Each receiver 52 is tuned to a respective one of the N possible microwave carrier frequencies. In the receiver 52 for which the currently received data packet is in band, the received signal is down-converted in a series of frequency steps to produce typically a 64 kHz IF signal which is applied to the processing unit 54 and sampled at 256 kHz by a 12 bit ADC (Analogue to Digital Converter). The processing unit 54 consists of a single extended 6U multi-layer printed circuit board, containing two 80 Mhz TMS320C50 fixed point digital signal processors, jointly providing 80 MIPS. The incoming data packet is demodulated and decoded in the processing unit 54 and the relevant IP request is then passed to the TCP/IP server 16 via a satellite communication server 56.

As mentioned earlier, the frequency of the transmitted signal can drift considerably over the satellite link. Indeed, the nominal 64 kHz IF signal produced by the burst receivers 52 can be in error by as much as 10 kHz. In order to accurately demodulate the received signal, the actual frequency of the signal needs to be correctly determined.

This is achieved in the processing unit 54 which determines the power spectrum of the signal in the frequency domain and hence at which frequency the power is greatest. In order to do this a Fast Fourier

Transform (FFT) is applied to the analog-to-digital converted input signal, transforming it from the time domain to the frequency domain. The frequency domain for the Fourier Transform is discretised into 256 bins each of size 1 kHz. On completion of the FFT, the power spectrum is analysed to determine in which of the frequency bins the power is greatest. The frequency corresponding to this bin is taken as being the correct frequency of the signal.

In the present embodiment of the invention, this frequency acquisition procedure is augmented in two ways. Firstly, a modified FFT is used, an Offset Fast Fourier Transform, as is known in the art. Using a standard FFT the frequency resolution is only half the frequency bin size, whereas using an OFFT can provide a frequency resolution as low as a quarter the frequency bin size. Secondly, the preamble bit reversals 101010101 ...etc. show up in the frequency domain power spectrum as two peaks (local maxima) separated by 32 kHz, centered about the correct value of the carrier frequency. This enables an even better estimation of the carrier frequency to be determined.

A variable frequency local oscillator (not shown) in the processing unit 54 generates an appropriate signal at the carrier frequency estimate obtained from the OFFT, which is then used to demodulate the received signal and hence reconstruct the encrypted and encoded IP packet. Any residual frequency errors manifest themselves as phase errors in the recovered data, but these can be removed using phase tracking techniques or differential demodulation, as is known in the art.

The final step in reconstructing the transmitted data packet is to recover the bit clock, in order to ensure that the demodulated data is correctly sampled. This is achieved in the processing unit 54 as schematically shown in Fig. 3. The demodulated data packet, A, is applied to a delay and add stage 66 where the data bits are delayed by a half bit period and modulo-2 added to the non-delayed data to give the signal C. This signal has a strong frequency component at the bit clock rate. The signal C is then applied to an Infinite Impulse Response filter 70, the waveform C having been converted at 68 from logic levels to positive and negative impulses to drive the filter. The IIR resonant centre frequency is chosen so that it corresponds to the bit rate clock. As a result of the applied impulses the filter resonates at its centre frequency (the bit clock frequency) to produce waveform D. This waveform is now hard limited at 72 back to logic levels to give waveform E, the recovered clock output.

The final data packet can now be correctly reconstructed and is then passed from the processing unit 54 via the satellite communication server 56 to the TCP/IP server 16 for connection to the internet 60. The connection 58 between the satellite communication server 56 is ideally at least a 1 MegaBit per second Duplex synchronous terrestrial circuit.

Data received from the internet 60 is broadcast via a Digital Video Broadcast (DVB) encoder 64 to all users as a 1 MegaBit per second time division multiplexed signal 62 on a predetermined frequency. Each user terminal 12 downloads all the broadcast data, only processing those packets which contain the user's IP address.

CLAIMS

1. A satellite communication system comprising a central broadcast station in satellite communication with a plurality of user terminals each of which can make requests for broadcast data from the central broadcast station, wherein each user terminal includes means for sending each user request as one or more data packets each of which is transmitted as a modulated carrier whose frequency is randomly selected from a set of N predetermined frequencies common to all the user terminals, each data packet including data identifying the particular user terminal from which it originates, and wherein the central broadcast station includes N channels each arranged to receive and demodulate data packets transmitted at a respective one of the N carrier frequencies.

2. A system as claimed in claim 1, wherein each user terminal includes means for modulating each data packet on a randomly selected one of N predetermined intermediate carrier frequencies and means for up-converting each intermediate carrier frequency to a respective one of N microwave carrier frequencies prior to transmission of the data packet.

3. A system as claimed in claim 2, wherein the central broadcast station includes means for down-converting the microwave carrier frequency of each received data packet to a nominal intermediate frequency, analog-to-digital converting the down-converted data packet, estimating the actual frequency of the down-converted data packet by applying a Fast Fourier Transform to the digital data

packet to provide a frequency domain power spectrum, and demodulating the digital data packet using the frequency thus estimated.

4. A system as claimed in claim 3, wherein each data packet includes a preamble containing digital data which provides, in the frequency domain power spectrum, two local maxima centered about the actual frequency of the down-converted data packet.

5. A system as claimed in claim 4, wherein the digital data comprises a plurality of bits which alternate in value.

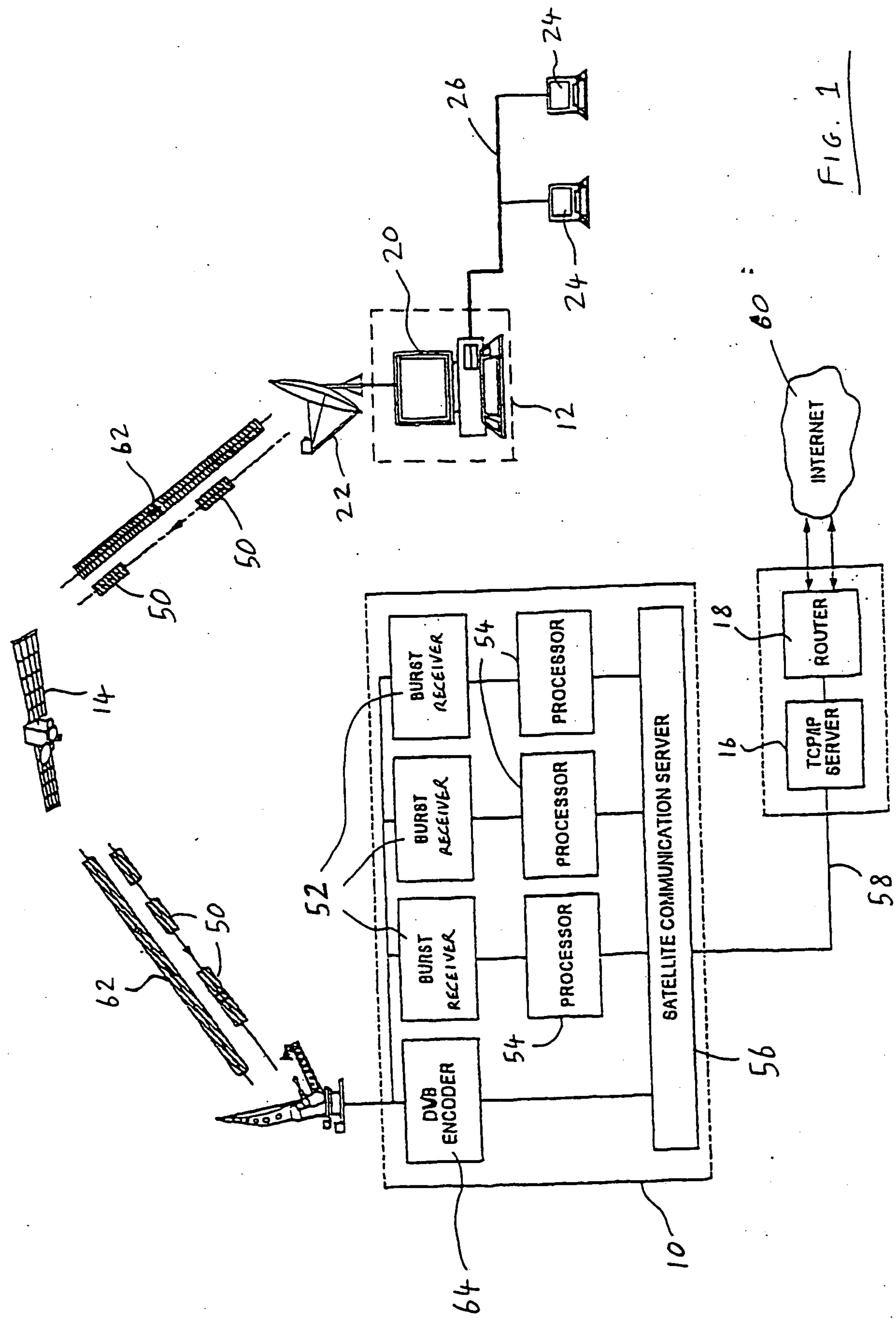
6. A system as claimed in claim 3, 4 or 5, wherein the Fast Fourier Transform is an Offset Fast Fourier Transform.

7. A system as claimed in any one of claims 3 to 6, wherein the central broadcast station includes means for recovering the bit clock of the demodulated data packet by delaying the data bits and adding them to the undelayed bits to provide a signal having a strong frequency component at the bit clock rate, applying the lastmentioned signal to a filter, and limiting the output of the filter to provide the bit clock, the central broadcast station further including means for decoding the data packet using the bit clock so recovered.

8. A system as claimed in any preceding claim, wherein the central broadcast station includes means for passing the decoded user request to the internet and for receiving data from the internet in response to such request.

9. A system as claimed in claim 8, wherein the central broadcast station includes means for broadcasting the data received from the internet to all user terminals.

10. A satellite communication system substantially as described herein with reference to the accompanying drawings.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TCP/IP SERVER
BURST RECEIVER
PROCESSOR
SATELLITE COMMUNICATION SERVER
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BURST RECEIVER
PROCESSOR
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DVB ENCODER
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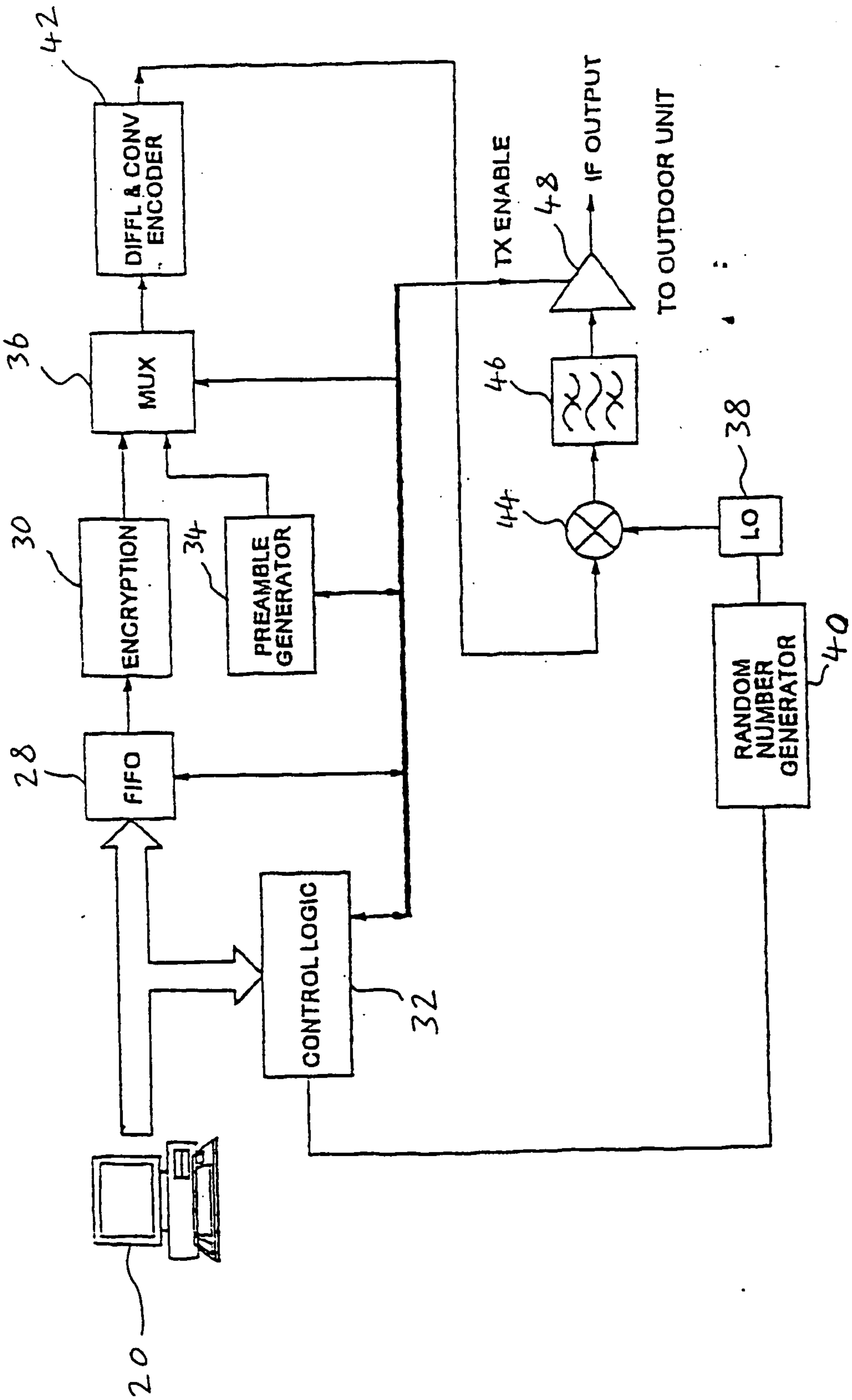
10
64

FIG. 1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MUX
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ENCRYPTION
30
PREAMBLE GENERATOR
34
FIFO
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IF OUTPUT
TO OUTDOOR UNIT
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44
LO
38
RANDOM NUMBER GENERATOR
40

FIG. 2

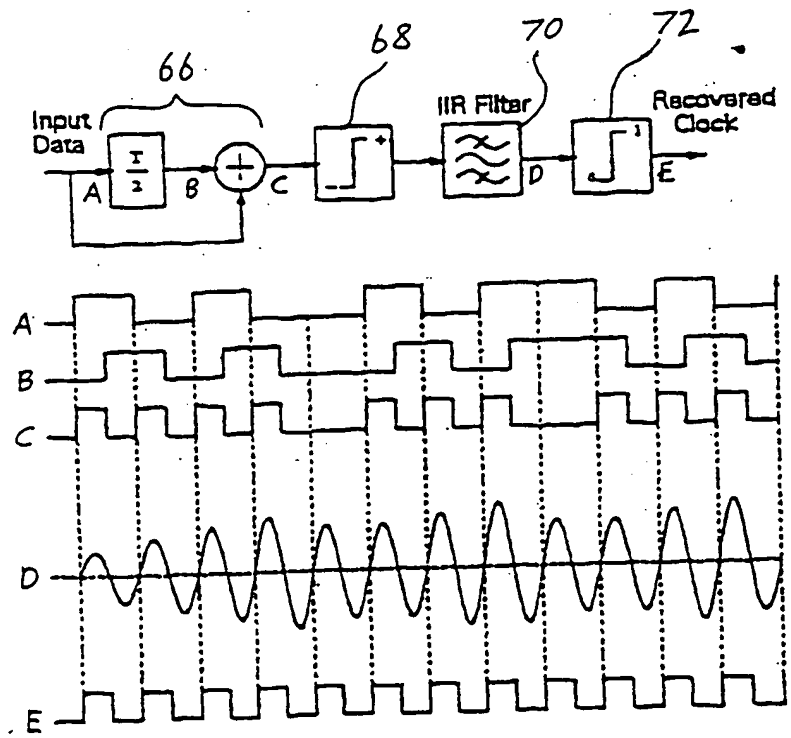

FIG. 3

INTERNATIONAL SEARCH REPORT

Inte ..ional Application No
PCT/IE 99/00015

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B7/208 H04B1/713

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 423 715 A (HUGHES AIRCRAFT CO) 24 April 1991 see abstract see column 2, line 5 - column 3, line 26 see claims 1-3; figures 1-5 ---	1-10
A	US 5 539 769 A (KOSKO BART ET AL) 23 July 1996 see abstract see column 1, line 23 - column 2, line 37 see figure 1A -----	1-10

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 June 1999	08/07/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lazaridis, P

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IE 99/00015

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 0423715	A	24-04-1991	US	5121408	A	09-06-1992
			DE	69027830	D	22-08-1996
			DE	69027830	T	28-11-1996
			IL	95819	A	26-08-1994
US 5539769	A	23-07-1996	NONE			

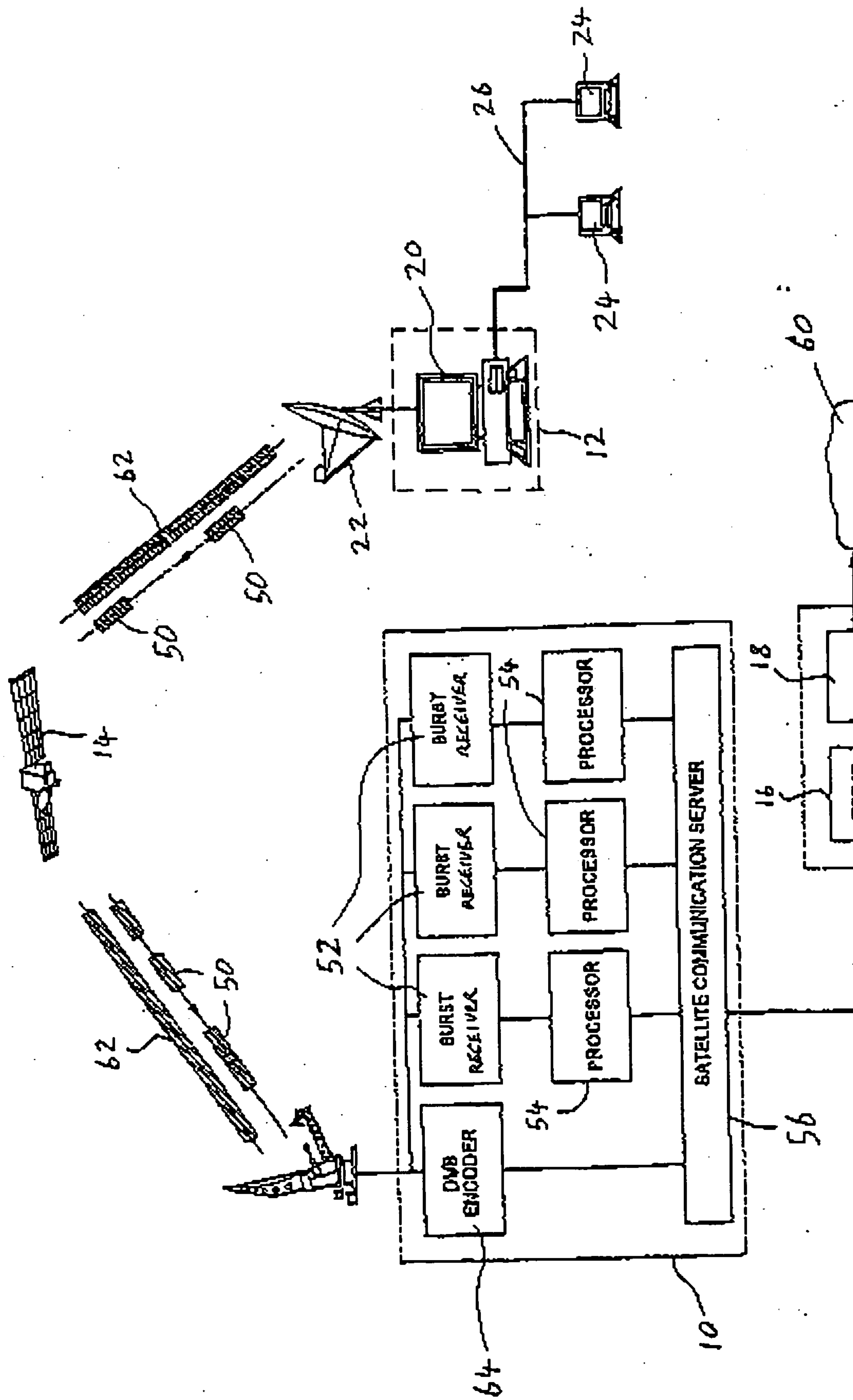
BURST RECEIVER
BURST RECEIVER
BURST RECEIVER
PROCESSOR
PROCESSOR
PROCESSOR
DVB ENCODER
SATELLITE COMMUNICATION SERVER
ROUTER
TCP/IP SERVER
INTERNET
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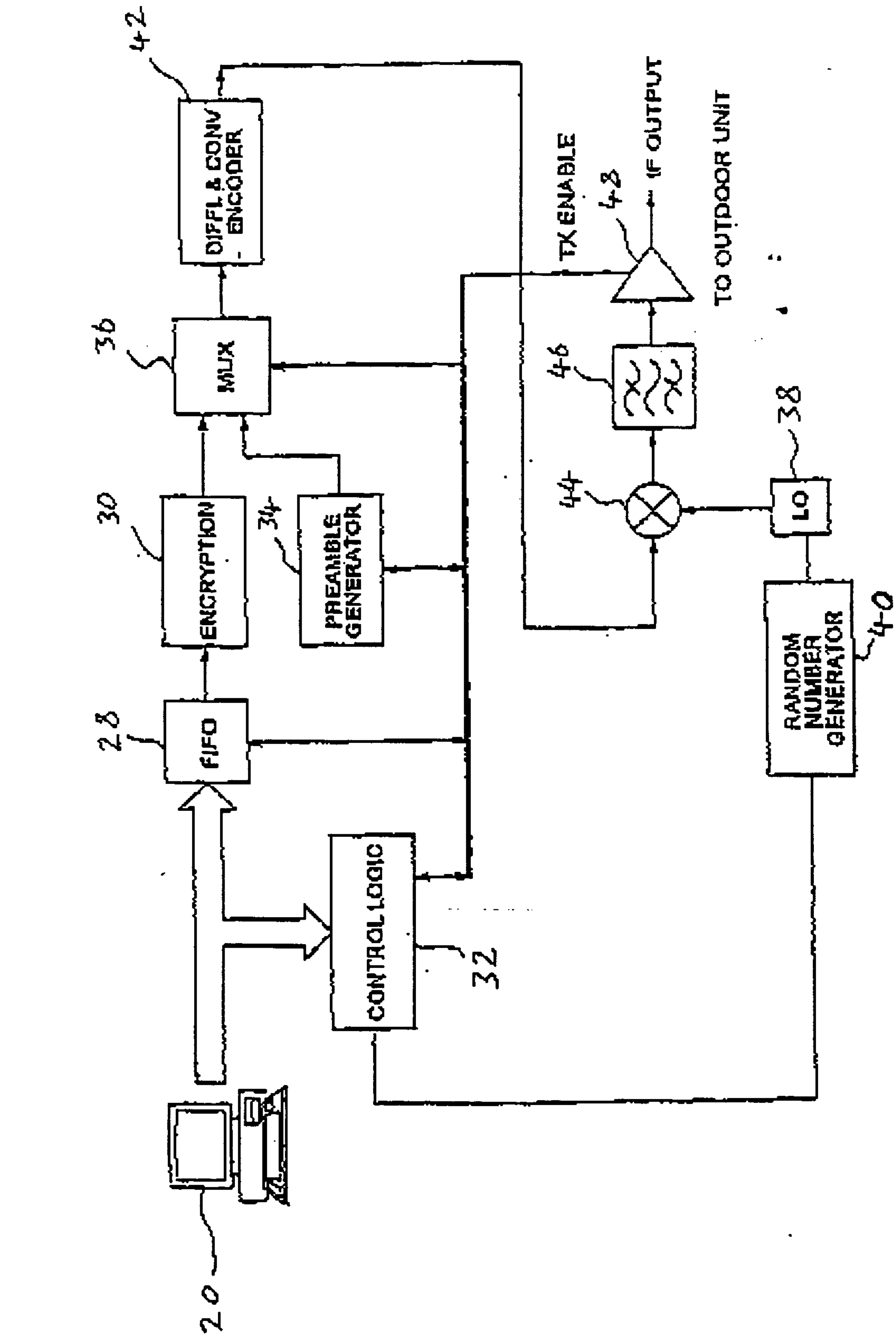
FIG. 1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CONTROL LOGIC
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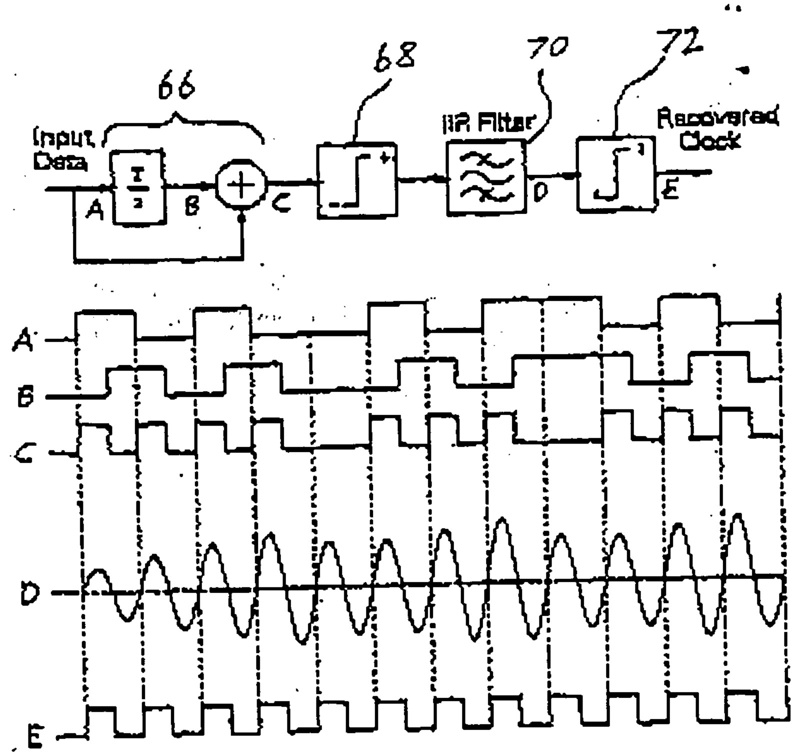
TX ENABLE
48
IF OUTPUT
TO OUTDOOR UNIT
46
44
38
LO
RANDOM NUMBER GENERATOR
40

FIG. 2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70
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Input Data
A
B
C
IIR Filter
D
E
Recovered Clock
A
B
C
D
E

FIG. 3